Film Flow along Tunnel Walls

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Dripping of liquid water into tunnels or caves affects natural processes (such as formation of speleothems) and is important to engineering applications (such as mining and geologic disposal of nuclear wastes). Current computer models of these processes assume that liquid water drips immediately after entering the tunnel. In contrast, recent field observations showed that film flow and wetting of tunnel walls result in a temporal and spatial lag between liquid emergence and subsequent dripping, and reduces the amount of dripping. Moreover, spreading of water on the tunnel walls enhances the potential for evaporation. The objective of this study was to assess how film flow along rough tunnel walls affects seepage and to provide a framework for realistic modeling of seepage and evaporation. In this research, conceptual models are developed by capitalizing on recent advances in our understanding and modeling of (1) unsaturated flow near and around tunnels, (2) characterization of unsaturated flow on rough surfaces, and (3) dripping from pendant rivulets. We show that film flow has the potential for diverting a significant portion of the flux of liquid entry into a tunnel. We derived an analytical expression for the threshold flux that results in dripping (seepage) and analyzed the implications for various cavity sizes and tunnel wall roughness features.

This work was supported by the Director, Office of Science, Office of Basic Energy Sciences, Division of Chemical Sciences, Geosciences, & Biosciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Session: H07 Recent Advances in Groundwater Hydrology (POSTER)
Index: 1875, 1899

Total Characters: 1780